(NASA-CR-193380) APOLLO 11 AT TWENTY-FIVE, VERSION 1.0 (Diskette) (Space Telescope Science Inst.)

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COVER:

Apollo at Twenty-Five [at top]
Text by Dr. Roger D. Launius, NASA History Office [at bottom]

Institutional Information:

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INTRODUCTION

On 25 May 1961, President John F. Kennedy announced in a speech on "Urgent National Needs"-billed as a second State of the Union message to the nation-a goal of sending an American safely to the Moon before the end of the decade. The impetus for this decision was the perceived imbalance of power and prestige during the Cold War between the United States and the Soviet Union in the spring of 1961. For Kennedy, the decision to conduct the Moon landing program was a strategic one directed at advancing the far-flung interests of the United States in the international arena.

The decision required much study and review prior to making it public, and after the announcement, tremendous expenditure and effort to make its promise a reality by 1969. Only the building of the Panama Canal rivaled the Apollo program's size as the largest non-military technological endeavor ever undertaken by the United States; only the Manhattan Project was comparable in a wartime setting. The human spaceflight imperative was a direct outgrowth of it; Projects Mercury (at least in its latter stages), Gemini, and Apollo were each designed to execute it. It was finally successfully accomplished on 20 July 1969, when Apollo 11's astronaut Neil A. Armstrong left the Lunar Module and set foot on the surface of the Moon.

In the end, a unique confluence of political neces- sity, personal commitment and activism, scientific and technological ability, economic prosperity, and public mood made possible the 1961 decision to carry out a forward-looking lunar landing program. It then fell to NASA and other organizations of the Federal Government to accomplish the task set out in a few short paragraphs by President Kennedy.

Project Apollo in general, and the flight of Apollo 11 in particular,should be viewed as a watershed in the nation's history. It was an endeavor that both demonstrated the technological and economic virtuosity of the United States and established its technological preeminence over rival nations-the primary goal of the program when first envisioned by the Kennedy Administration in 1961.

Project Apollo left several important legacies. First, and probably most important, the Apollo program successfully accomplished the political goals for which it had been created. Thus, when at the time of the Apollo 11 landing, Mission Control in Houston flashed the words of President Kennedy announcing the Apollo commitment on its big screen and followed them with "TASK ACCOMPLISHED, July 1969," it seemed a great understatement. Not only had humans walked on the surface of the Moon, but, by the end of the decade, America was the unrivaled world leader in space.

Second, Project Apollo was a triumph of manage- ment in meeting enormously difficult systems engineering, technological, and organizational integration requirements. NASA leaders always contended that Apollo was much more a management exercise than anything else, and that the technological challenge, while sophisticated and impressive, was largely within grasp at the time of the 1961 decision. Understanding the management of complex structures for the successful completion of a multifarious task was a critical outgrowth of the Apollo effort.

Third, Project Apollo forced the people of the world to view the planet Earth in a new way. Apollo 8 was critical to this fundamental change, as it treated the world to the first pictures of the Earth from afar. The view of the rising Earth as seen by the Apollo 8 crew during their orbital flight around the Moon (it appears as the last image in this Electronic PictureBook) showed a world that is singularly beautiful, but fragile. The modern environmental movement was galvanized in part by this new perception of the planet and the attendant realization of the need to protect it and the life that it supports.

Finally, the Apollo program, while an enormous achievement, left a divided legacy for NASA and the aerospace community. The perceived "golden age" of Apollo created for the agency an expectation that the direction of any major space goal from the President would always bring NASA a broad consensus of support and provide it with the resources and license to dispense them as it saw fit. Something most NASA officials did not understand at the time of the Moon landing in 1969, however, was that Apollo had not been conducted under normal political circumstances and that the exceptional circumstances surrounding Apollo would not be repeated.

The Apollo effort was, therefore, an anomaly in the national decision-making process. The dilemma of the "golden age" of Apollo has been difficult to overcome, but moving beyond the Apollo program to embrace future opportunities has been an important goal of the agency's leadership in the recent past. Exploration of the Solar System and the universe remains as enticing a goal and as important an objective for humanity as it ever has been. Project Apollo was an important early step in this ongoing process of exploration.

1 Kennedy Addressing Joint Session of Congress

In announcing the lunar landing commitment, President John F. Kennedy told the American people in May 1961:

> If we are to win the battle that is going on around the world between freedom and tyranny, if we are to win the battle for men's minds, the dramatic achievements in space which occurred in recent weeks should have made clear to us all, as did the Sputnik in 1957, the impact of this adventure on the minds of men everywhere who are attempting to make a determination of which road they should take.... We go into space because whatever mankind must undertake, free men must fully share.
>
> ...I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish.

The President had correctly gauged the mood of the nation. His commitment captured the American imagination and was met with overwhelming support.

2 Gagarin Preparing for Flight

The decision to initiate the lunar landing program was spurred in large part by the Soviet Union. On 12 April 1961, Soviet Cosmonaut Yuri Gagarin, shown here, flew a one-orbit mission aboard the spacecraft Vostok 1 , thus becoming the first human in space. The great success of this feat made the gregarious Gagarin a global hero, and he became an effective spokesman for the Soviet Union until his death in 1968 from an unfortunate aircraft accident. The successful venture took place not long after President Kennedy assumed office in January.

On 20 April 1961, Kennedy called on Vice President and head of the National Aeronautics and Space Council, Lyndon B. Johnson, to review options for recovering national pride by carrying out some prestigious space effort. In particular, Kennedy asked, "Do we have a chance of beating the Soviets by putting a laboratory in space, or by a trip around the moon, or by a rocket to go to the moon and back with a man? Is there any other space program that promises dramatic results in which we could win?"

Lyndon Johnson responded by polling senior government and industry officials about space capabilities. Wernher von Braun, then director of NASA's George C. Marshall Space Flight Center at Huntsville, Alabama, and head of the Saturn V booster program, told the Vice President that "we have a sporting chance of sending a 3-man crew around the moon ahead of the Soviets" and "an excellent chance of beating the Soviets to the first landing of a crew on the moon (including return capability, of course)."

On 28 April 1961, Johnson told the President: "The U.S. can, if it will, firm up its objectives and employ its resources with a reasonable chance of attaining world leadership in space during this decade," and recommended committing the nation to a lunar landing.

3 Apollo's Budget

The first challenge NASA leaders faced in meeting the presidential mandate was securing funding. Initial NASA estimates of the cost of Project Apollo were about $20 billion through the end of the decade-a figure of over $150 billion in 1995 dollars when accounting for inflation. The actual cost was $21.35 billion through the first lunar landing. In all, the program cost about $25 billion.

The funding profile depicted on this graph shows the Apollo budget and its relationship to the total NASA budget. At the height of the program, Apollo was consuming more than half of the funds allocated to the agency. This was especially true during the peak research and development years of 1964 to 1967. The actual flights to the Moon, which took place between 1969 and 1972, were not the most expensive part of the effort. The real expense was in the design and development of spacecraft and launch vehicles, the construction of facilities, and the training of crews and other NASA personnel to perform the actual landings.

Because of these requirements, the space agency's annual budget increased from $500 million in 1960 to a high point of $5.2 billion in 1965, representing 5.3 percent of the federal budget for that year. A comparable percentage of the more than $1.3 trillion federal budget in 1994 would have equaled more than $65 billion for NASA, whereas the agency's actual budget for the year was less than $15 billion.

4 The Apollo Workforce

Funding was not the only critical component for Project Apollo. To realize the goal of Apollo under the strict time constraints mandated by the President, personnel had to be mobilized. This mobilization effort took two forms: growth in civil service and a significant increase in the use of contractors.

As shown in this chart, the number of NASA civil service (GS) employees grew from about 10,000 in 1960 to about 36,000 in 1966, whereas contractor personnel during the peak years of work on Apollo rose from 36,500 in 1960 to 376,700 in 1965. Thus, private industry, research institutions, and universities provided the majority of personnel working on Apollo.

5 Expanding the Infrastructure

NASA moved quickly during the early 1960s to expand its physical capacity so that it could accomplish Apollo. In 1960, the space agency consisted of a small headquarters in Washington, its three inherited NACA research centers, the Jet Propulsion Laboratory, the Goddard Space Flight Center, and the Marshall Space Flight Center.

With the advent of Apollo, these installations grew rapidly. In addition, NASA added three new facilities specifically to meet the demands of the lunar landing program. In 1962, it created the Manned Spacecraft Center (renamed the Lyndon B. Johnson Space Center in 1973), near Houston, Texas, to design the Apollo spacecraft and the launch platform for the lunar lander. This center also became the home of NASA's astronauts and the site of mission control. NASA then greatly expanded the Launch Operations Center at Cape Canaveral on Florida's eastern seacoast. Renamed the John F. Kennedy Space Center on 29 November 1963, this installation's massive and expensive Launch Complex 39 was the site of all Apollo lunar launches.

Additionally, the spaceport's Vehicle Assembly Building, shown in the left of this image, is a huge and expensive 36-story structure where the Saturn/Apollo rockets were assembled. Finally, in October 1961, NASA created the Mississippi Test Facility (renamed the John C. Stennis Space Center in 1988) to support the development of the Saturn launch vehicle. The cost of this expansion was more than 2.2 billion over the decade, with 90 percent of it expended before 1966.

6 The Management Team

The mobilization of resources was not the only challenge facing those charged with meeting President Kennedy's goal. NASA had to meld disparate institutional cultures and approaches into an inclusive organization moving along a single unified path. To bring a semblance of order to the program, NASA brought in military managers to oversee Apollo, and developed an effective program management concept. One of the fundamental tenets of this program management concept was that three critical factors-cost, schedule, and reliability-were interrelated and had to be managed as a group.

The program management design was recognized as a critical component of Project Apollo's success in November 1968, when Science magazine, the publication of the American Association for the Advancement of Science, observed:

> In terms of numbers of dollars or of men, NASA has not been our largest national undertaking, but in terms of complexity, rate of growth, and technological sophistication it has been unique. . . . It may turn out that [the space program's] most valuable spin-off of all will be human rather than technological: better knowledge of how to plan, coordinate, and monitor the multitudinous and varied activities of the organizations required to accomplish great social undertakings.

Apollo's senior leadership team ensured that the technical skills available to NASA were properly used and managed. Pictured here at the time of the first lunar landing, the team consisted of (L-R): George E. Mueller, head of the Office of Manned Space Flight; Samuel C. Phillips, Apollo Program Manager; Kurt Debus, Kennedy Space Center director; Robert R. Gilruth, Manned Spacecraft Center director; and Wernher von Braun, Marshall Space Flight Center director.

7 The Apollo Mission Profile

One of the critical early management decisions made by NASA was the method of going to the Moon. No controversy in Project Apollo more significantly caught up the tenor of competing constituencies in NASA than this one. Three basic approaches were advanced to accomplish the lunar mission:

1. Direct Ascent called for the construction of a huge booster that launched a spacecraft, sent it on a course directly to the Moon, landed a large vehicle, and sent some part of it back to Earth. Even if other factors had not impaired the possibility of direct ascent, the huge cost and technological sophistication of building such a large rocket quickly ruled out the option despite the conceptual simplicity of the direct ascent method.

2. Earth-Orbit Rendezvous called for launching various modules required for the Moon trip into an orbit above the Earth, where they would rendezvous, be assembled into a single system, refueled, and sent to the Moon. This method could be accomplished using the Saturn launch vehicle already under development by NASA. It also necessitated the establishment of a space station in Earth orbit to serve as the lunar mission's rendezvous,assembly, and refueling point.

3. Lunar-Orbit Rendezvous proposed sending the entire lunar spacecraft up in one launch. It would head to the Moon, enter into orbit, and dispatch a small lander to the lunar surface.

In 1961 and 1962 this issue was one of the most hotly debated in NASA. This image shows the lunar-orbit rendezvous approach-the mission profile eventually adopted by NASA. The trip to the Moon is depicted in the lower half of the image; the return to Earth is detailed in the upper half.

8 Von Braun Briefing Engineers

The last of the program management team to agree to the lunar-orbit rendezvous approach was Marshall Space Flight Center Director Wernher von Braun (shown here, arms folded, in the center of a group of engineers) and his associates. This group favored the Earth-orbit rendezvous because the direct ascent approach was technologically unfeasible before the end of the 1960s, because it provided a logical rationale for a space station, and because it ensured an extension of the Marshall workload (something that was always important to center directors competing inside the agency for personnel and other resources).

At an all-day meeting on 7 June 1962, at Marshall, NASA leaders met to hash out these differences, with the debate getting heated at times. After more than six hours of discussion, von Braun finally gave in to the lunar-orbit rendezvous mode, saying that its advocates had demonstrated adequately its feasibility and that any further contention would jeopardize the President's timetable.

9 The Kennedy Visit to MSFC

After internal dissension over the Apollo mission profile had quieted, NASA moved to announce the Moon landing mode to the public in the summer of 1962. As it prepared to do so, however, Kennedy's Science Adviser, Jerome B. Wiesner, raised objections because of the inherent risk it brought to the crew.

The issue reached a climax at the Marshall Space Flight Center in September 1962 when President Kennedy, Wiesner, Webb, and several other Washington figures visited Wernher von Braun. As the entourage viewed a mock-up of a Saturn V first stage booster during a photo opportunity for the media, Kennedy nonchalantly mentioned to von Braun, "I understand you and Jerry [Wiesner] disagree about the right way to go to the moon." Von Braun acknowledged this disagreement, but when Wiesner began to explain his concern, Webb, who had been quiet until this point, began to argue with him "for being on the wrong side of the issue."

While the mode decision had been an un- interesting technical issue before, it immediately became a political concern debated in the press for days thereafter. The science advisor to British Prime Minister Harold Macmillan, who had accompanied Wiesner on the trip, later asked Kennedy on Air Force One how the debate would turn out. The President told him that Wiesner would lose, explaining "Webb's got all the money, and Jerry's only got me."

Kennedy was right; Webb lined up political support in Washington for the lunar-orbit rendezvous mode and announced it as a final decision on 7 November 1962. This photo depicts the 11 September 1962 visit to the Marshall Space Flight Center to review the Saturn development effort:

(L-R) President John F. Kennedy; Wernher von Braun, director of Marshall Space Flight Center; James E. Webb, NASA Administrator; Vice President Lyndon B. Johnson; Secretary of Defense Robert S. McNamara; Jerome B. Wiesner, President's Science Advisor; and Harold Brown, director of DOD research and development.

10 Mercury Launch

At the time of the announcement of Project Apollo by President Kennedy in May 1961, NASA was still consumed with the task of placing an American in orbit through Project Mercury. Stubborn problems arose, however, at seemingly every turn. The first space flight of an astronaut, made by Alan B. Shepard, had been postponed for weeks so NASA engineers could resolve numerous details. It took place finally on 5 May 1961, less than three weeks before the Apollo announcement. A second suborbital flight followed on 21 July 1961.

On 20 February 1962, John Glenn became the first American to circle the Earth, making three orbits in his Friendship 7 Mercury spacecraft. This flight was not without problems; Glenn flew parts of the last two orbits manually because of an autopilot failure, and he had to leave his normally jettisoned retrorocket pack attached to his capsule during reentry because of a loose heat shield.

Friendship 7 is shown here sitting atop an Atlas launch vehicle as it departs from the launch platform at Cape Canaveral, Florida. The Atlas was fueled by a combination of Liquid Oxygen (LOX) and RP-1 aviation fuel. Because of the LOX's ultra-cold temperature, it causes ice from condensation to form on the outer skin of the booster, as can be seen in the image.

Three more successful Mercury flights took place during 1962 and 1963. Scott Carpenter made three orbits on 20 May 1962, and, on 3 October 1962, Walter Schirra flew six orbits. The capstone of Project Mercury was the 15-16 May 1963 flight of Gordon Cooper, who circled the Earth 22 times in 34 hours. With the completion of this flight, the goals of Project Mercury-to successfully orbit a human in space, to explore aspects of tracking and control, and to learn about microgravity and other biomedical issues associated with spaceflight-were successfully accomplished.

11 Gemini EVA

In 1962, NASA program managers perceived still a huge gap in the capability for human spaceflight between the knowledge and experience acquired with Mercury and what would be required for an Apollo landing on the Moon. The problem fell into three major issue areas. The first issue was the need to be able in space to locate, maneuver toward, and rendezvous and dock with another spacecraft. The second concerned the ability of astronauts to work outside a spacecraft. The third involved the collection of more sophisticated physiological data about the human response to extended spaceflight. To gain experience in these areas before Apollo could be readied for flight, NASA devised the dual-astronaut spacecraft, Gemini.

Problems with the Gemini program abounded from the start. The Titan launch vehicle had longitudinal oscillations, called the "pogo" effect because it resembled the behavior of a child on a pogo stick. Overcoming this problem required engineering imagination and long hours of overtime to stabilize fuel flow and maintain vehicle control. By the end of 1964, most of the difficulties with Gemini had been resolved, albeit at great expense, and the program was ready for flight.

The first operational mission took place on 23 March 1965, when Gus Grissom and John W. Young orbited the Earth. The next mission, Gemini 4 , was flown in June 1965, and stayed aloft for four days. During this flight, astronaut Edward H. White II performed the first American extra-vehicular activity (EVA) or spacewalk, as shown in this image. Eight more Gemini missions followed through November 1966. Despite problems great and small encountered on virtually all of the missions, the program achieved its goals.

As a technological learning program, Gemini was a success, with 52 different experiments performed on the ten missions. The bank of data acquired from Gemini helped to bridge the gap between Mercury and what would be required to complete Apollo within the time constraints directed by the President.

12 Surveyor on the Moon

NASA sent several satellites to the Moon prior to the first landing by astronauts. Mission planners needed to know the composition and geography of the Moon, and the nature of the lunar surface. Was it solid enough to support a lander, or was it composed of dust that would swallow up the spacecraft? Would communications systems work on the Moon? Would other factors-geology, geography, radiation, etc.-affect the astronauts? To answer these questions, three distinct satellite research programs emerged to study the Moon.

The first of these was Project Ranger, which provided close-up photographs of the surface before crashing. The second project was the Lunar Orbiter, which surveyed the surface from above. NASA launched five Lunar Orbiter satellites between 10 August 1966 and 1 August 1967, all successfully achieving their objectives. The last program, Project Surveyor, soft-landed satellites on the Moon. A small craft with tripod landing legs, it could take post- landing photographs and perform a variety of other measurements. Surveyor 1 landed on the Moon on 2 June 1966 and transmitted more than 10,000 high- quality photographs of the surface. In all, five Surveyors were sent to the Moon, and yielded significant scientific data both for Apollo and for the broader lunar science community.

This photograph of Surveyor 3 was taken by the astronauts of Apollo 12, who landed near there in November 1969. The Lunar Module can be seen in the distance.

13 Saturn V Diagram

The Saturn booster development project was critical to the success of Project Apollo. After the development of smaller models, the Marshall Space Flight Center built the largest launch vehicle of the Saturn family, the Saturn V . Standing 363 feet tall, with three stages, this vehicle would take astronauts to the Moon and return them safely to Earth. The first stage generated 7.5 million pounds of thrust from five massive engines developed for the system. These engines, known as the F-1, were some of the most significant engineering accomplishments of the program, requiring the development of new alloys and different construction techniques to withstand the extreme heat and shock of firing. (Note: Certain reports that circulated in the media several years ago indicated that the plans for the building of the Saturn V had been destroyed in a fit of bureaucratic small-mindedness or error. This rumor is not true. The plans are retired to the Federal Records Center at East Point, Georgia, where they are housed in some 500 record boxes and on numerous microform masters.)

14 Saturn V Stages

The initial static test of the first stage of the Saturn V rocket, on 16 April 1965, brought home to many that the Kennedy goal was within technological grasp. For others, it signaled the magic of technological effort; one engineer even characterized rocket engine technology as a "black art" without rational principles. This first stage (SI-C) was manufactured in New Orleans, sent by barge to the Mississippi Test Facility (as shown here on the East Pearl River, where it is ready to be unloaded for testing) and, when judged acceptable, transported by water to the Kennedy Space Center.

The second stage of the Saturn V rocket, S-II, presented enormous challenges to NASA engineers and very nearly caused the lunar landing goal to be missed. Consisting of five engines burning LOX and liquid hydrogen, this stage could deliver 1 million pounds of thrust. It was always behind schedule, and required constant attention and additional funding to ensure completion by the deadline for a lunar landing. In contrast, both the first and third stages of this Saturn vehicle development program moved forward relatively smoothly.

The Douglas Aircraft Corporation manufactured the S-IVB, third stage, of the Saturn V rocket. A much smaller primary component that generated 200,000 pounds of thrust, it was manufactured and tested in California, and shipped to the Kennedy Space Center where it was assembled into the remainder of the Saturn components.

15 Saturn V at Night

NASA employed more than 500 contractors to build the Saturn launch vehicle. In addition, NASA dealt with more than 250 subcontractors who provided millions of parts and components, all of which had to meet exacting specifications for performance and reliability. The total cost expended on development of the Saturn launch vehicle was massive, amounting to $9.3 billion. So huge was the overall Apollo endeavor that NASA's procurement actions rose from roughly 44,000 in 1960 to almost 300,000 by 1965 (see Image #4).

Here the fully-assembled Saturn V three-stage rocket with the Apollo 6 spacecraft atop it are outlined against the Florida skyline as they leave the Vehicle Assembly Building at Kennedy Space Center.

16 The Debate Over Testing

Despite the massive effort involved with designing and building the Saturn V, the biggest problem lay not with the hardware, but with the clash of philosophies toward development and test. Wernher von Braun's "Rocket Team" had made important technological contributions and enjoyed popular acclaim as a result of conservative engineering practices that took minutely incremental approaches toward test and verification. They tested each component of each system individually and then assembled them for a long series of ground tests. Then they would launch each stage individually before assembling the whole system for a long series of flight tests. While this practice ensured thoroughness, it was both costly and time-consuming, and NASA had neither commodity to expend.

George E. Mueller, third from left in this photograph and head of NASA's Office of Manned Space Flight, disagreed with the approach of von Braun, shown here on the left. (Robert Gilruth is in the center.) Drawing on his experience with the Air Force and aerospace industry, and shadowed by the twin bugaboos of schedule and cost, Mueller advocated what he called the "all-up" concept in which the entire Apollo-Saturn system was tested together in flight without the laborious preliminaries.

Moving forward with this calculated gamble, the first Saturn V test launch took place on 9 November 1967, with the entire Apollo-Saturn combination. A second test followed on 4 April 1968, and even though it was only partially successful because the second stage shut off prematurely and the third stage- needed to start the Apollo payload into lunar trajectory-failed, Mueller declared that the test program had been completed and that the next launch would have astronauts aboard. The gamble paid off. In 17 test and 15 piloted launches, the Saturn booster family scored a 100 percent launch reliability rate.

17 Apollo Spacecraft Diagram

Almost with the announcement of the lunar landing commitment in 1961, NASA technicians began a crash program to develop a reasonable configuration for the trip to lunar orbit and back. What they came up with was a three-person command module capable of sustaining human life for two weeks or more in either Earth orbit or in a lunar trajectory; a service module holding oxygen, fuel, maneuvering rockets, fuel cells, and other expendable and life support equipment that could be jettisoned upon reentry to Earth; a retrorocket package attached to the service module for slowing to prepare for reentry; and a launch escape system that was discarded upon achieving orbit. The tear-drop shaped command module had two hatches, one on the side for entry and exit of the crew at the beginning and end of the flight and one in the nose with a docking collar for use in moving to and from the lunar landing vehicle.

Work on the Apollo spacecraft stretched from 28 November 1961, when the prime contract for its development was lett.